# The Effects of a Physical Activity Program and a Cognitive Training Program on the Long-Term Memory and Selective Attention of Older Adults: A Comparative Study



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(Article begins on next page)

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## TABLE OF CONTENTS LISTING

The table of contents for the journal will list your paper exactly as it appears below:

*Activities, Adaptation & Aging*, 00:1–15, 2014

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# The Effects of a Physical Activity Program and a Cognitive Training Program on the Long-Term Memory and Selective Attention of Older Adults: A Comparative Study

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*The study aims to evaluate the effects of a physical activity program and a cognitive training program on the long-term memory and selective attention of older adults by comparing the effects of the activities. Twenty-four older adults participated in a physical activity program, 24 in a cognitive training program, and 24 were considered the control group. The physical activity and the cognitive training had a significant effect on long-term memory but no difference between the interventions was found. Only the physical activity improved selective attention. Physical activity programs appear to be the most effective interventions in the promotion of older adults cognitive functions.*

*KEYWORDS* *older adults, memory, attention, physical activity, cognitive training*

The growing size of the older population in our society is a demographic phenomenon that is widely recognized and accepted. According to the Global Health Observatory of the World Health Organization, average life

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expectancy is 68 years, but the global population that is currently 60 years old can expect to live another 19 years (World Health Organization, 2011). Moreover, the United Nations Department of Economics and Social Affairs (2009) reported that adults older than age 80 represent 1.5% of the worldwide population and that this proportion is expected to increase to 4.3% by 2050.

Despite the increase in life expectancy, different studies have highlighted that the prolongation of the life span is associated with a deterioration in psychological, physical, and cognitive conditions (Aromaa & Koskinen, 2004; Stenzelius, Westergreen, Thorneman, & Rahm Hallberg, 2005; World Health Organization, 2002). Considering specifically the cognitive changes, various studies have identified neuron loss and alterations in synaptic density as the main causes of cognitive impairment in older age (Hof & Morrison, 2004; Masliah, Mallory, Hansen, DeTeresa, & Terry, 1993). The neuronal changes have severe consequences on different cognitive functions, including memory and attention, even if these functions do not change uniformly (Hedden & Gabrieli, 2004). In fact, it is long-term memory, the memory system for permanently storing and retrieving information, that is mainly affected by aging while other memory functions, such as short-term memory, remain relatively stable (Grady & Craik, 2000; Ishihara, Gondo, & Poon, 2002; Mattay et al., 2006). Also, attention competences are not entirely influenced by aging, with impairments involved in particular selective attention (Chao & Knight, 1997; Commodari & Guarnera, 2008; West, 2004), which is the ability to focus on a specific stimulus, inhibiting others that occur simultaneously.

The cognitive decline of long-term memory and selective attention is particularly relevant for the well-being and autonomy of older adults. In fact, the maintenance of cognitive performance is strictly related to the correct execution of daily physical tasks (Tabbarah, Crimmins, & Seeman, 2001) and activities of daily living (Lu, Zhen, Yang, & Liang, 2003) such as cooking, shopping, housekeeping, and taking care of financial matters (Perrig-Chiello, Perrig, Uebelbacher, & Stahelin, 2006). Memory and attention impairments have strong consequences on the lives of older adults, so the maintenance of these cognitive abilities and the prevention of severe cognitive deterioration represent imperative objectives.

For this reason, the scientific community is currently identifying effective strategies and activities that could maintain the cognitive abilities of older adults. Among all the possible programs, the cognitive training and the physical activity programs are the main activities studied by researchers. The meta-analysis by Colcombe and Kramer (2003) extensively demonstrated that physical activity programs have positive effects on the cognitive functions of older adults. Moreover, these results have been confirmed by other reviews and meta-analyses that have summarized the results of many studies about this topic (Angevaren, Aufdemkampe, Verhaar, Aleman, & Vanhees, 2008; Heyn, Abreu, & Ottenbacher, 2004; Kramer & Erickson, 2007b; Van Uffelen, Chin A Paw, Hopman-Rock, & van Mechelen, 2008). Specifically, memory and attention can be enhanced thanks to participation in physical activity programs. In fact, different studies have shown that older adults that have been involved in these programs have improved their long-term memory (Ruscheweyh et al., 2011) and selective attention (Owsley & McGwin, 2004; Roth, Goode, Clay, & Ball, 2003).

With regard to cognitive training, various studies have confirmed the effectiveness of this type of activity (Ball et al., 2002; Wolinski et al., 2006), even if there are still some unanswered questions about the long-term effects of this training, especially in relation to the possibility of delaying Alzheimer's disease (Papp, Walsh, & Snyder, 2009). However, cognitive training seems to be effective on specific cognitive functions, including long-term memory (Belleville et al., 2006) and selective attention (Mozolic, Long, Morgan, Rawley-Payne, & Laurienti, 2011). Moreover, it has been shown that unique cognitive training can improve both memory ability and attention ability (Bernhardt, Maurer, & Frolich, 2002).

Thus, there is strong evidence about the protective effect of physical activity programs and cognitive training on the long-term memory and selective attention of older adults, and there are a growing number of proposals of these activities for them in our society. However, it is not clear which of these activities are more effective in the improvement of long-term memory and selective attention. In fact, research has focused on a single activity, either cognitive or physical, without comparing them. Comparing two different types of activities is fundamental because it allows us both to identify which of these activities is more effective and to understand why one intervention category is more effective than another. Despite the importance of this question, to our knowledge no studies have attempted to compare the effects of a physical activity program and cognitive training on the same cognitive functions of older adults. This study aims to fill this gap by comparing the possible improvements in the long-term memory and selective attention of two groups of older adults that participated in a physical activity program and cognitive training.

## AIMS

This study aims first to evaluate the effects of a physical activity program and cognitive training on the long-term memory and selective attention of two groups of older adults. The second aim is to compare the magnitude of the possible effects of the two interventions, highlighting which of the two activities is the most effective.

First, we expected that participation in both the physical activity program and the cognitive training would enhance the memory and the attention of older adults. As shown, there is a large amount of literature that confirmed the positive effects of these interventions on the cognitive status of older adults (Colcombe & Kramer, 2003; Ruscheweyh et al., 2011). In fact, physical activity programs have requirements for older adults that concern not only their physical abilities but also their cognitive functions, such as listening to the requests of the trainer and memorizing the sequences of movement. With regard to cognitive training, this activity is designed to stimulate specific cognitive functions, such as memory and attention, with specific exercises and strategies. Second, we expected that the cognitive training would enhance significantly more the memory and the attention of older adults than the physical activity, because the training was created to impact specifically and directly on the memory and attention of older adults.

Thus, our study can be summarized by the following research questions: Did older adults that participated in a physical activity program and cognitive training enhance their level of long-term memory and selective attention? Are there significant differences in the level of improvement of long-term memory and selective attention between older adults from the physical activity program and older adults from the cognitive training group?

## METHODS

An experimental research design was implemented to investigate the effects of the physical activity program and the cognitive training (experimental conditions) with respect to the control group. Initially we investigated the cognitive status of older adults, involving in the study only individuals without severe cognitive impairment. Before and after the treatments we administered two neuropsychological tests for long-term memory and selective attention to evaluate the possible positive effects of participation in these activities. The same tests were administered to older adults from the physical activity and cognitive training groups and to the control group.

### The Physical Activity Program

The training consisted of a twice-weekly intervention of 75 minutes per session. The physical activity program was carried out in small groups and qualified instructors conducted the sessions. All the coaches had a university degree in physical education and sports-related fields and were specialized in physical fitness training for the elderly. The intervention protocol, as advised by the American College of Sports Medicine et al. (2009), focused on three specific objectives: aerobic endurance, mobility, and strength. The first 10 minutes of exercise consisted of a warm-up activity of walking around an indoor track at a slow rate/rhythm of low intensity, followed by four accelerations of stride for 30 seconds interspersed with 1 minute of slow stride. A 50-minute endurance exercise period followed the warm-up, consisting primarily of walking with direction changes, accelerations and decelerations of rhythm, changes of gait, and balance exercises. During the 16 weeks of training the exercise intensity was increased. After this, in the same place, 10 minutes of strength training provided closed kinetic chain exercises using body weight as resistance for all major muscle groups of the lower extremity (half squat—knee flexion around 90 degrees; quarter squat—knee flexion around 120 degrees; lunge—during the lunge, the knee does not touch the floor; side lunge; and calf raise). The intensity was increased by the number of repetitions and the recovery time between series. The last 5 minutes were used for cooling down and resting. The intervention was organized so as to reproduce the movements and gestures of daily life, bearing in mind the three previous aims.

## The Cognitive Training

The cognitive training, "Lab I—cognitive empowerment," was designed by the Department of Psychology of the University of Padua, Italy, to increase specifically the memory ability of older adults in their daily lives (Vranic & Borella, 2012). The main objectives of the cognitive training were: (a) to share in a group setting the experiences of the participants in their daily problems linked with cognitive impairments; (b) to provide specific knowledge about the different memory structures and their functioning and changes during aging; and (c) to instruct and train the participants in the main memory strategies for storing a large amount of information, increasing the functioning of the memory (i.e., method of loci, mental visualization). Most of the cognitive training time was dedicated to mental training using these strategies, especially to retrieve lists of words, and training also on episodic memory, short-term memory, and autobiographical memory with specific exercises. The older adults were involved in this cognitive training for 4 months once per week: The training had a duration of 1.5 hours and was conducted in small groups by trained psychologists with a degree in developmental psychology.

## Participants

Our study was approved by the Ethical Committee of the University of Turin and the participants were informed that participation in the study was voluntary and confidential. The participants were recruited by phone and they did not receive any incentive for participation. All the selected individuals agreed to participate and gave their written informed consent, in accordance with Italian law and the ethical code of the Italian Association of Psychology (1997). A list of 200 older adults belonging to senior centers in the city of Turin was offered by the Piedmont region, which has these data. From this starting list of 200 older adults, we recruited randomly 100 older adults, obtaining the consent of 79 older adults. Seven older adults did not confirm their participation before the assignment. In the final sample of 72 participants, three groups were implemented: a cognitive training group, a physical activity training group, and a control group. Each older person was randomly assigned to one of the three conditions (physical, cognitive training, or control).

The three criteria for the inclusion in the study project were: age older than 65 years; absence of serious chronic and/or acute diseases; and intact cognitive functions, which was directly verified by the researchers. The Mini Mental State Examination Test (Folstein, Folstein, & McHugh, 1975) was administered to evaluate cognitive functions, and all the participants reached or exceeded the minimum score of 24.

The final sample comprised 72 older adults, 23 of whom were males (32%; 8 in the physical activity group, 6 in the cognitive training group, and 9 in the control group) and 49 of whom were females (68%; 16 in the physical activity group, 18 in the cognitive training group, and 15 in the control group). We did not find gender differences between the two groups ($\chi = .61$, $df = 2$, $p = .73$). The mean age was 73 ($SD = 5.1$) for the cognitive training group, 71 ($SD = 4.6$) for the physical activity group, and 69 ($SD = 5.1$) for the control group. There was a significant age difference between the control group and the cognitive training group (Tukey post-hoc test $p < .05$). The main sociodemographic characteristics of the participants are summarized in Table 1.

## Procedure

In the present study we considered specifically the long-term memory and the selective attention of the older persons that participated in the physical activity program and the cognitive training.

The Rey Auditory Verbal Learning Test (RAVLT; Rey, 1964) was administered before and after the two treatments and to the control group to evaluate the long-term memory of the participants. This test consists of a list of 15 words orally presented to the participants. The list is read five times by the researcher; after each repetition, the participants have to recall as many words as possible from the list. After five repetitions of the list, the participants are involved in other cognitive tests that do not involve memory functions. After 20 minutes, the participants again have to recall spontaneously the words. The number of words recalled by the participants after 20 minutes represents a measure of long-term memory (range 0–15).

**TABLE 1** Sociodemographic and Baseline Characteristics of Study Participants

| | | Physical Activity | | Cognitive Training | | Control Group | |
|---|---|---|---|---|---|---|---|
| | | *N* | % | *N* | % | *N* | % |
| Gender (*N*) | Women | 16 | 67 | 18 | 75 | 15 | 62.5 |
| | Men | 8 | 33 | 6 | 25 | 9 | 37.5 |
| Level of education (*N*) | Low | 18 | 75 | 17 | 71 | 10 | 42 |
| | High | 6 | 25 | 7 | 29 | 14 | 58 |
| Family condition | Never married | 3 | 8 | 1 | 4 | 1 | 4 |
| | Married | 14 | 62 | 10 | 42 | 15 | 63 |
| | Widow | 7 | 30 | 13 | 54 | 6 | 25 |
| | Divorced | – | – | – | – | 2 | 8 |
| Past job | Manual labor | 11 | 46 | 11 | 46 | 12 | 50 |
| | Nonmanual labor | 13 | 54 | 13 | 54 | 12 | 50 |
| | | *M* (*SD*) | | *M* (*SD*) | | *M* (*SD*) | |
| Age | | 71 (4.6) | | 73 (5.1) | | 69 (5.1) | |
| Rey Auditory Verbal Learning Test score | | 7.6 (2.7) | | 8.9 (2.8) | | 9.3 (2.7) | |
| Attentional matrices test | | 47 (8) | | 50 (6.5) | | 46.4 (7.3) | |

*Note*: Level of education—low, corresponding to compulsory education (primary school) and high, corresponding to additional noncompulsory education. $M$ = mean; $SD$ = standard deviation.

The attentional matrices (Spinnler & Tognoni, 1987) were administered before and after the treatments to evaluate the selective attention of the participants. This test consists of three matrices of 130 numbers presented in 13 lines of 10 numbers. The participants have to identify and mark specific target numbers that are among other numbers that act as distractors. For the first matrix, the target number is 5, for the second matrix the target numbers are 2 and 6, and for the third matrix the target numbers are 1, 4, and 9. The participants have 45 seconds to complete every matrix. Every target number appears 10 times in the matrix and the total number of target numbers marked by the participants (range 0–60) represents a measure of the selective attention. In the post-test we administered a parallel version of the two tests to avoid the risk of memory effects.

## Data and Statistical Analysis

First, we compared the RAVLT and attentional matrices scores of the participants of the three groups at baseline with ANOVA analysis to verify that older adults from the physical and cognitive training groups and control group were balanced in RAVLT and attentional matrices scores at baseline.

Second, we tested the differences between the experimental and control groups by analysis of covariance (ANCOVA) for post-test RAVLT and attentional matrices scores with group as main effect (physical group and training group vs. control group) and the baseline RAVLT and attentional matrices scores as covariates. According to Van Breukelen (2006) and Rausch, Maxwell, and Kelley (2003), in randomized studies with a treatment assignment the ANCOVA analysis of the outcome with the baseline as covariate is the best and most appropriate solution. The analyses were controlled for age and gender.

## RESULTS

The ANOVA analysis revealed that the physical activity group ($M = 7.6$, $SD = 2.7$), the cognitive training group ($M = 8.9$, $SD = 2.8$), and the control group ($M = 9.3$, $SD = 2.7$) were balanced in RAVLT scores before the beginning of the activities ($F(2, 69) = 2.34$, $p = .10$). Similarly, the physical activity group ($M = 47$, $SD = 8$), the cognitive training group ($M = 50$, $SD = 6.5$), and the control group ($M = 46.4$, $SD = 7.3$) were balanced in attentional matrices score ($F(2, 69) = 1.4$, $p = .23$).

With regard to the RAVLT scores at the post-test, ANCOVA analysis revealed significant differences among groups ($F = 4.5$, $p < .01$, $\eta^2 = 12$). Q5
Comparing the three groups using the Bonferroni test, data showed a significant difference between the control group and the physical activity group (mean difference $= -1.783$, $p < .05$) and the cognitive training group (mean difference $= -1.68$, $p < .05$). No significant differences were found between the physical activity group and the cognitive training group (mean difference $= 0.51$, $p = 1$).

With regard to the attentional matrices score, the analysis confirmed a significant difference among groups ($F = 6.2$, $p < .01$, $\eta^2 = 15$). The Q6
Bonferroni test indicated a significant difference between the control group and the physical activity group (mean difference $= -5.8$, $p = .01$). No significant differences were found between the control group and the cognitive training group (mean difference $= -2.3$, $p = .54$). The results of the ANCOVA analysis are summarized in Table 2. Figures 1 and 2 represent the change

**TABLE 2** Analysis of Covariance (ANCOVA)

| | Physical Activity Group | | Cognitive Training Group | | Control Group | | |
|---|---|---|---|---|---|---|---|
| | Pretest *M* (*SD*) | Post-test *M* (*SD*) | Pretest *M* (*SD*) | Post-test *M* (*SD*) | Pretest *M* (*SD*) | Post-test *M* (*SD*) | ANCOVA |
| Rey Auditory Verbal Learning test scores | 7.6 (2.7) | 10.2 (2.9) | 8.9) (2.8) | 11.1 (2.9) | 9.3 (2.7) | 9.6 (2.9) | $F = 4.5$ $p < .01$ $\eta^2 = .12$ |
| Attentional matrices scores | 46.4 (8) | 54.3 (7) | 50 (6.5) | 52.3 (5.8) | 47 (7.3) | 48.5 (7.3) | $F = 6.2$ $p < .01$ $\eta^2 = .15$ |

*Note*: Baseline values were used as covariate. $M$ = mean; $SD$ = standard deviation.

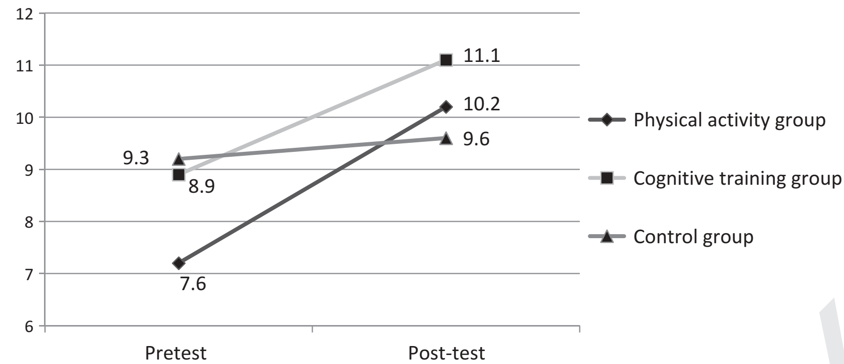


**FIGURE 1** Rey Auditory Verbal Learning Test scores for physical activity group, cognitive training group, and control group.

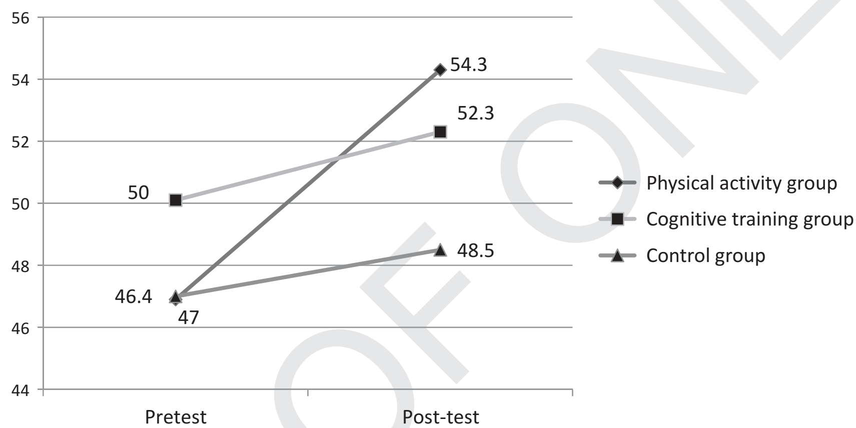


**FIGURE 2** Attentional matrices scores for physical activity group, cognitive training group, and control group.

between the pretest and the post-test in the RAVLT and attentional matrices scores of the physical activity group, the cognitive training group, and the control group.

## DISCUSSION

This study aimed to evaluate the effects of physical activity training and cognitive training on the long-term memory and selective attention of a group of older adults by comparing the magnitude of the effects between the two interventions.

Among all the changes related to aging, the cognitive modifications are particularly relevant for the well-being and autonomy of older adults.

Long-term memory (Grady & Craik, 2000; Ishihara et al., 2002) and selective attention (Chao & Knight, 1997; Commodari & Guarnera, 2008; West, 2004) are the main cognitive functions affected by aging and this condition has a significant impact on the well-being and autonomy of older adults (Lu et al., 2003; Perrig-Chiello et al., 2006). Physical activity and cognitive training programs have been identified as effective interventions that maintain and promote the cognitive functions of older adults, especially memory (Belleville et al., 2006; Ruscheweyh et al., 2011) and attention (Mozolic et al., 2011; Owsley & McGwin, 2004). However, it is not clear which of these activities is more effective: promoting the best intervention for older adults and also understanding the possible mechanisms that make one intervention more effective than others have become crucial points.

We verified and compared the effects of a physical activity program, designed to improve physical abilities, and a cognitive training program, designed to improve the memory skills in different groups of older adults. First, considering the large amount of literature (Belleville et al., 2006; Mozolic et al., 2011; Owsley & McGwin, 2004; Ruscheweyh et al., 2011), we expected a significant effect from both interventions on long-term memory and selective attention. Our hypothesis was confirmed only in part. In fact, the older adults that participated in the two activities increased significantly their long-term memory but only the older adults from the physical activity program improved significantly their selective attention compared to the control group. These results represent a further demonstration of the positive effects of physical activity for older adults, but they leave unanswered questions about the efficacy of cognitive training, especially regarding the generalization of the effects. In fact, the cognitive training was only effective on long-term memory while no improvements in selective attention were highlighted.

Second, we expected that older adults from the cognitive training group would have improved their long-term memory and selective attention significantly more than older adults from the physical activity program. Our expectation was justified by the characteristics of the cognitive training, designed precisely to improve memory and also impact on the attention of older adults. Unexpectedly, our expectation was not confirmed.

With regard to long-term memory, the data did not show any differences between the improvement in older adults from the physical activity program and the older adults from the cognitive training group: The two groups improved their long-term memory in the same way. In terms of selective attention, as previously mentioned, the cognitive training was not effective for improving the selective attention of older adults.

There are several reasons that could explain these results. First, the physical activity program is designed to improve older adults physical functions, but indirectly it also stimulates their cognitive resources. In fact, with regard to long-term memory, our physical activity program required the older adults to memorize gradually more difficult patterns of movements and to recall the exercise without any help from the instructor at the beginning of every new session. With regard to memory skill, it is interesting to note that a nonspecific activity, such as the physical activity program, has had the same effects on the memory of older adults as a specific activity designed to empower the memory of older adults. Moreover, the physical activity program constantly stimulated the selective attention of the older adults. In fact, selective attention was necessary to learn new patterns of movements, to control them actively, and to inhibit other information in the environment. Thus, older adults have to use many cognitive resources to execute correctly the tasks of the physical activity program.

Second, a physical training program that involves actions linked with daily life could be more effective than a specific training program that has a more theoretical approach. In fact, the difficulties of the physical activity tasks are gradual while the requirements of the cognitive training program can appear immediately complex because they are far removed from their daily experiences. Moreover, older adults are probably also more motivated and they participate with more commitment if they perceive the connection of these activities with their daily life and the positive effects that they can enjoy.

Third, there is confirmation from neuroscience that physical activity has a strong impact on the brain structure of older adults (Hollman, Struder, Tagarakis, & King, 2007). According to Kramer and Erickson (2007a), randomized clinical trials involving older adults have already shown that physical training can change the brain structure, increasing gray matter in the frontal and temporal cortex and anterior white matter (Colcombe et al., 2006) or increasing the cerebral blood volume (Pereira et al., 2006). These results confirm that physical exercise provides multiple routes to enhancing cognitive vitality by improving the molecular and cellular structure and function of the brain (Kramer, Colcombe, McAuley, Scalf, & Erickson, 2005). In sum, all these reasons can account for our findings about the cognitive effects of physical training.

## Limitations of the Present Study

However, we have to take into account some limitations of the study, including the small size of the samples. In order to obtain more reliable results it is important to involve a larger number of older adults. Moreover, we cannot ignore the fact that our findings are strictly correlated with the specific characteristics of the physical activity program and the cognitive training of our study. The training programs were different in terms of duration (3 hours per week for the physical activity vs. 1.5 hours per week for the cognitive training), objectives, and activities. For this reason, caution must be taken regarding the generalization of our results.

However, the main aim of the study was to perform a preliminary comparison between these two activities, representing a first attempt to identify the most effective intervention for improvement of the memory and attention of older adults. Our data seem to suggest that the physical activity programs are complete interventions that can act at the same time directly on the physical functions and indirectly on the cognitive skills of older adults, as already highlighted by various studies (Colcombe & Kramer, 2003; Van Uffelen et al., 2008). In particular, the improvements in long-term memory and selective attention due to participation in the physical activity program are similar or even greater than those due to participation in a specific cognitive training program.

The physical activity program was likely more effective than the cognitive training because it is an ecological activity in which body and mind are trained together in a natural and familiar way. Moreover, interventions in which older adults recognize a direct and immediate purpose for their life are more able to capture interest and commitment than abstract and complex activities such as cognitive training. Based on our preliminary study, effective interventions on the memory and attention of older adults should be ecological and recognizable in their real usefulness for daily life. For these reasons, physical activity programs are recommended for older adults that are still able to participate. In fact, physical activity programs enhance physical and cognitive functioning. Cognitive training cannot reproduce these combined effects because it only impacts cognitive functioning. Moreover, in our study, the magnitude of the effects on cognitive functioning is similar to or almost lower than that of physical activity.

Future research should deepen this comparison between these activities in order to clarify definitively whether physical activity programs are really more effective than cognitive training on cognitive skills, confirming that physical activity programs are the best strategy for facing the cognitive and physical effects of aging.

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